Standards of Effluents to Rivers with Particular Reference to Industrial Effluents

In 1966 the Ministry published a Memorandum entitled "Technical Problems of River Authorities and Sewage Disposal Authorities in Laying down and Complying with Limits of Quality for Effluents More Restrictive than those of The Royal Commission". The long title was necessary to explain the very limited field with which it was concerned; it dealt with local authority effluents only, it was concerned only with the "Royal Commission" criteria of quality and closely related matters, and discussion was limited to those cases where standards more strict than normal might be required. It has since been suggested that it would be helpful if other situations, including particularly those in which industrial effluents are major factors, were discussed, and this is what the present paper, foreshadowed in Circular No. 64/67, sets out to do. Because it deals with a much wider range of subjects it is much more than a follow-up paper. Much of what was said in the first paper, however, also applies to this one, but the arguments there, though referred to, will not be repeated here in extenso. It would be as well if any reader read them both.

INDUSTRIAL AND DOMESTIC EFFLUENTS COMPARED

The previous paper made the assumption that almost all inland sewage treatment plants would produce, and would be required to produce, an effluent conforming with the Royal Commission standard at least. It was pointed out that this could normally be done at a cost which could not be regarded as other than reasonable. Moreover, it has been general policy (deliberate or not) for the last 30 or 40 years for inland sewage treatment plants to be designed to produce such effluents. The fact that some treatment plants did not in fact (and still do not) do so was not important in that particular context. The assumption that they should do so made it possible for that paper to concentrate on those cases where that standard was not sufficiently high.

It should perhaps be noted that the first paper did not say that the assumption was justifiable in every case. All it said was that if an inland sewage disposal authority believed that a Royal Commission standard was unnecessarily high or too difficult to attain, then the onus should be on them to prove it.

Theoretically, it is quite illogical to require one standard to be adopted more or less as a matter of course and others (more restrictive than this) to be fully justified. The illogicality was accepted for sufficiently good reasons and, within limits and while confined to sewage discharges, no great objection to it was expected. But there would be very considerable objections from industry if the principle were extended to industrial effluents, and if it were said that these, too, should generally conform to the Royal Commission standard more or less as a matter of course. In fact, of course, this paper says no such thing. Any "norm" for the quality of industrial discharges is (unless vast numbers of exceptions are allowed) quite out of the question because it cannot be assumed that a particular quality of effluent is either necessary for the sake of the river, reasonable in cost, practical, or even possible in the circumstances of a particular case. It is therefore reasonable to expect a river authority to be able to justify all standards laid down for industrial effluents and not just exceptionally high ones.

This difference of attitude of river authorities towards local authority and direct industrial discharges could lead to difficulty, and this must be faced. The river authority might decide, in a particular case, that the river would be reasonably satisfactory if the industrial discharge were, say, 50/50,* and, in view of the quality of the raw effluent or site limitation, might be prepared to write such a quality into their consent. But they would normally ask a local authority, with an adjacent discharge, for 30/20 (the "norm"). It might also be that the best way of dealing with the firm's effluent would be to discharge to the local sewers, in which case the purified effluent (mixed with the local sewage effluent) would have to conform to the 30/20 standard. The firm would doubtless ask the question: "Why, if we discharge direct, will a 50/50 standard suffice, but if we discharge next door (the local authority's works) must we pay for treatment to a higher standard?" There is, of course, no logical answer to this question; one cannot start with an admitted illogicality and then by argument make it logical! But there are things that can be said about it. First, it might well be as cheap or cheaper for the firm to discharge to the local sewers and pay for full treatment than to treat the effluent themselves to the relaxed standard. Secondly, if pressed by the firm to make both standards the same in the interests of equity, the river authority would no doubt agree to make them both 30/20! But that would not satisfy the firm. Thirdly, the river authority might consider whether the circumstances combined to make the whole case the exceptional one where a relaxation of the Royal Commission standard for the sewage disposal authority was indeed justified. It is not known that any river authority has done this formally, but there certainly have been cases of a very polluting direct industrial discharge being diverted to the sewers on the understanding that some deterioration of the authorities' effluent would be tolerated, at least for a period.

Mention has been made above of equity, and although this cannot be discussed here in detail, a word or two may be necessary, for it is not uncommon for an industrialist to feel that he is being discriminated against, and this prevents the co-operation in river pollution control that is so necessary for its successful operation. On several occasions industrialists have put the point to the Minister that they are being asked to pay, say, four times as much for the treatment of their effluent as a competitor 50 miles away, and this is held to give the competitor an unfair advantage. It certainly gives him an advantage, but if the ratio is a true reflection of the cost of purification wherein is it unfair? A firm in Dundee with a market in London does not formally appeal to the Minister of Transport because his costs of carriage are greater than those of a competitor in Dunstable.

With the best will in the world, it is often difficult to decide where equity lies. Two industrialists on the same stretch of river may produce effluents of similar nature and in equal quantity. The river authority may well decide that in equity and for the sake of the river both should be subject to a B.O.D. limit of 20 p.p.m. Fair enough; why not? But if the wastes as produced have B.O.D's respectively of 1,000 p.p.m. and 100 p.p.m., the first firm might well ask why they should purify their waste by 98% whereas the second one gets away with 80%. Such a question cannot be dismissed out of hand; for one thing, it may not actually be possible to purify the effluent by as much as 98%.

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* In this paper figures expressed in the form 50/50 relate to suspended solids content and biochemical oxygen demand (B.O.D) in that order and in mg/l.

For the sake of progress, it is to be hoped that it will never be necessary to pursue all such questions to the bitter end. The value of co-operation between discharger and river authority was mentioned in the previous paper and emphasised in the Ministry Circular published at the same time. This is equally necessary with industrial dischargers, and they and the river authority (and the sewage disposal authority if they come into it) should explain their difficulties and requirements to each other and attempt to appreciate those of the other parties. This should engender a climate in which difficulties of the type now being considered are resolved.

Often it is the view of the river authority that it would be better to divert a direct industrial discharge to the local sewers for treatment with the sewage of the district. In many cases they are right, and it has been general policy since the passing of the Public Health (Drainage of Trade Premises) Act 1937 to encourage what was even then a marked trend in that direction. In cases they consider suitable, river authorities will doubtless want to convince an industrial discharger of the desirability of such action. How they should do this is not the concern of this paper. But it is desirable to point out that, although on balance treatment of industrial effluents with sewage is clearly a good thing, not all the arguments are in favour of it. If it is necessary to lay long lengths of sewers or pipelines it may become very expensive. A point which has not been so widely appreciated is that it may cause trouble at storm overflows. When an industrial effluent is treated where it is produced its volume should not be greatly increased in wet weather and all of it can therefore be treated. If discharged to combined sewers, however, a proportion will be discharged untreated (or only partially treated) in times of heavy rain, and this could give trouble which could be most expensive to rectify. It is important that the river authority should take this possibility into account when deciding its policy on individual effluents. Often somewhat increased storm sewage pollution may be judged a small price to pay for the removal of a regular, highly polluting direct discharge. It would be unfortunate if a river authority encouraged a sewage treatment authority to accept an industrial effluent and then, later, complained about a storm discharge to which they would have raised no objection in the absence of the industrial effluent. No case is known where this has occurred, but it clearly could do so, for there are instances where storm discharges are complained of principally because of the presence of constituents of industrial effluents. This paragraph is therefore only a warning.

CRITERIA OF QUALITY

For discharges of purified domestic sewage the criteria considered in the previous paper — suspended solids, B.O.D., occasionally ammonia and, conceivably, dissolved oxygen — have proved sufficient to control their quality. The probability is that this will always be the case. If new chemicals are developed for general use in the home, and if these resist known treatment processes and have adverse effects on the river, there would be little point in a river authority laying down limits of concentration for them. The sewage disposal authority would be able to do nothing about them, being unable either to prevent their discharge into the sewer or to remove them from the sewage. The proper way to deal with a problem of this kind would be to consider it on a national basis, as has been done, with considerable success, in the matter of synthetic detergents.

With industrial discharges the situation is quite different. There is no question, for instance, of the discharges originating in millions of small sources. Moreover, industrial firms are directly responsible to the local authority or river authority for their discharges, and the receiving authority has adequate powers of control. Industry must also be deemed to know the properties of the substances it uses and produces, and to pursue its activities in the knowledge that it must satisfy the reasonable demands of the authority which receives its effluent. And the discharges are often large and important enough to warrant individual consideration.

This is not to say that no problem of industrial discharges could advantageously be tackled on a national scale. For instance, non-ionic surface active substances which are biologically resistant are widely used in some industries, and these can give rise to adverse effects on rivers. With such wide use, it becomes a question whether a national effort to secure the development of degradable alternatives or the imposing of restrictions by local and river authorities is the better way of solving the problem. It might well be that both could play a part. There have also been some individual effluent problems requiring research to which national funds have contributed.

Nevertheless, in the main, prevention of pollution by industrial effluents is a matter for river authorities, and effective control lies in limiting the discharge of polluting substances. These are so variable and often so different from the polluting materials in domestic sewage that it would be very surprising if the criteria of quality already mentioned were sufficient to control them. In many cases they are not; in some, they are not applicable at all.

A book on the chemical analysis of sewage and industrial effluents now in preparation will describe tests for at least 50 properties or substances, most of which could properly, on some occasions, figure in river authority and local authority consents. It is plain that the subject of quality criteria for industrial effluents is a very wide one.

However, many individual industrial discharges may be relatively easy to deal with as far as consents are concerned. If it is known that its chief polluting constituent is, say, an iron salt, then a suitable upper limit of concentration which can be allowed (no doubt incorporating a factor of safety) can be worked out. and a simple condition written into a consent. If it is known that an effluent is produced solely in the manufacture of food, then there may be no need to consider whether limits for toxic metals should appear in the consent. And so on.

The matter becomes much more difficult, however, when the effluent is from a local authority works which receives not only domestic sewage but effluents from a wide variety of industries. It may contain a number of toxic metals, cyanides, phenols, pesticides, and even undesirable concentrations of neutral salts, together with a number of complicated organic compounds whose exact nature is unknown and the effect of which on rivers has never been studied. What sort of consent conditions are suited to such an effluent? Should the river authority do its best to cover all eventualities, most of which may never arise, or should it rely on its powers of review to incorporate limits as they become necessary? There is an obvious danger in the latter alternative: insufficient time may have elapsed since the previous review, or since the original consent, to allow a new review to be made. Yet the first alternative, theoretically at least, could produce a formidable crop of difficulties if the consent were challenged.

Some river authorities, in dealing with local authority effluents which contain, or which might contain, a variety of industrial effluents, do attempt, so far as they can, to provide for the worst by incorporating in their consents limits for a considerable number of contaminants, either individually or by groups. Thus, limits are laid down for cyanides, phenols and certain toxic metals; the last mentioned are sometimes grouped and a limit laid down for the total. So far as is known such a consent has never been formally challenged, and it cannot therefore be said that river authorities should not issue consents of this kind. Indeed, it must be emphasised that no attempt is made in this paper (or the previous one) to encroach upon the powers of river authorities to frame conditions which they believe to be suitable to the cases before them. But it may be useful to point to situations which might arise (a) if the sewage treatment authority appealed against the conditions, and (b) if they did not .

If there was an appeal the river authority would, of course, try to justify the conditions, and might be challenged to prove every one individually. They would no doubt produce basic data on toxicity and other properties and explain how they had taken account of the dilution available, the fate of the material in the river, the use to which the river was put, the interaction between one particular impurity and another, and other relevant matters. A good deal of argument could take place on all these matters. Whether the authority would prove their case is not at issue at the moment. The point is that a great deal of time and effort would have been spent in resolving issues of which only a minority, and possible none of them, would ever become reality. It would appear that there are better ways of spending time and money.

If there were no appeal, it might well be because the local authority knew that they could conform to the standards regarding special substances without trying, e.g. if they had no metal wastes they would automatically conform to the toxic metals limits laid down. This calls for the comment that standards which are conformed with without trying are hardly worth while laying down. But suppose a new trader now applied to discharge an effluent which might result in the local authority's effluent failing to comply with the river authority's conditions. The local authority would have no option but to refuse. If the trader appealed, the council would have what would appear to be the perfect answer to it: if they accepted the effluent they would be liable to prosecution. If the trader said that the condition which the local authority would be breaking was far too restrictive, the reply would have to be that that could not be argued, since the condition had been originally accepted and no appeal against it was now possible. The trader would doubtless feel that somehow he had been cheated of his rights, and it is always possible that he was right in his contention that the condition in question was too restrictive. It would, of course, be possible for the Minister to take the problem into his own hands and require the river authority to modify its condition, but the whole situation would be most unpleasant and its resolution would require much time and effort.

It would appear that there is a way of avoiding both these sets of difficulties. It could be done by confining the conditions to those properties and substances which did require realistic limitation (suspended solids, B.O.D. and, in certain cases, ammonia, some metals and perhaps other substances), and mentioning the other possibilities in the description of the effluent. In the simplest case, that of an effluent not containing industrial effluent, the consent could read: "This consent relates to an effluent from domestic sewage only", and some such phraseology has sometimes been used. In more complicated circumstances, where much industrial effluent is present already, it could read: "This consent relates to an effluent which does not contain more than X mg/l in all of the following metals, Y mg/l of phenols . . ." Provided the values of X and Y were below that which the river authority were prepared to allow if it became necessary and above that which the effluent contains or is likely to contain unless some new industrial effluents are admitted to the sewers, then there would be no need for the local authority to object and no need for the river authority to be prepared to justify X and Y absolutely. If at any time the local authority wished to have the permitted metal content (or the content of any other named impurities) increased or to accept an industrial effluent to which the consent did not relate, they would have to make a fresh application because the discharge would be a new or altered one.

Such a proceeding would appear to have advantages to all parties. First, the river authority would be spared the effort of attempting to determine exactly the limits they would be prepared to allow for the substances specified, secure in the knowledge that they could not be discharged without a new application which would allow them to fix a limit. They might never be called upon to do this, and even if they were it might only be in relation to one or two constituents. Secondly, the local authority would not wonder whether to appeal or not (so far as those particular substances were concerned) since, if necessary, they could always raise the issue at any time by making a fresh application and appealing against the conditions of that consent if they thought fit. Thirdly, if the reason for a new application was the desire of a trader to discharge an effluent to the sewers, it would bring the trader into more or less direct contact with the river authority, because it would clearly be necessary for the local authority to bring in the trader in support of its new application. Fourthly, (which is largely the converse of thirdly), it would enable the river authority to have its say in negotiations between a trader and a local authority on matters which are likely to affect it. At present, a harbour authority is an "interested body", but the river authority, oddly enough, is not. It is suggested, therefore, that river authorities consider the possibilities of this mode of operation.

It is realised, of course, that local authorities may refuse to accept industrial effluents on other grounds than their effect on the river. The matter is not dealt with in this paper.

CLASSIFICATION OF INDUSTRIAL EFFLUENTS

Industrial effluents are so varied in nature and composition that whatever classification is employed some of them will appear in more than one class and a few will defy any attempt at classification. Nevertheless, even imperfect classification facilitates discussion, and it may be useful to consider the following classes:—

(1) Effluents from food and drink manufacture.
(2) Other organic effluents.
(3) Effluents containing metals and cyanides.
(4) Chemical effluents.

Radioactive effluents are ignored as being dealt with under special legislation.

EFFLUENTS FROM FOOD AND DRINK MANUFACTURE

The main characteristic of these effluents is that the important compounds they contain are natural organic compounds. At least, they are natural in the sense that they readily form part of the normal biological cycle and break down under the influence of bacteria and other organisms, aerobically, anaerobically, or both, to form products indistinguishable from those produced in the decay of animal and vegetable matter. Effluents from the manufacture of sugar, malt, beer, cider, soft drinks, cheese, and from the processing and preservation of milk, vegetables, meat, poultry and so on are in this class. Their similarity to domestic sewage is more important than their differences. They do not, of course, contain such numbers of intestinal bacteria and other organisms which could produce disease on ingestion. The chemical identity of the contaminants present is doubtless very different (if evaporated down some would produce a nourishing, if not attractive, food; the same can hardly be said of sewage!), and the proportion of nitrogen to carbon may also be different. But their response to biological treatment, and, in particular, their chief effects on a river, are broadly the same, and accordingly the same criteria of effluent quality should suffice.

These effluents can be treated with domestic sewage, and more often than not they are in fact so treated. Then they should present the river authority with no new problem, and what was said in the previous paper will generally apply. Effluents from sewage works receiving them would generally be expected to conform at least to the Royal Commission Standard if discharged to inland watercourses.

These effluents can also be treated by sewage treatment processes in the absence of sewage, though sometimes the nutrient balance must be adjusted. It is perfectly possible to purify them to the Royal Commission Standard, but it has been concluded earlier that unless the river really requires this it should not necessarily be demanded. It is not easy to decide what should be demanded, since several conflicting factors need to be taken into consideration. It may never be possible to deduce a figure and be able to establish it beyond argument. Certainly none can be suggested here, since it has already been concluded that each case may deserve separate consideration. But a discussion of the important factors may be useful.

In the first place, it is not the B.O.D. or suspended solids content in milligrammes per litre that is the real measure of the pollution load; the real measure is these concentrations multiplied by the volume. As a first approximation, the effect on the river is proportional to this product. This being the case, there would be no obvious answer if a manufacturer maintained that, whereas he could not produce a B.O.D. of 20 mg/l in his 2 m.g.d. of effluent, but (by reducing his activities or economising in or re-using water) he could produce a B.O.D. of 40 mg/l in only 1 m.g.d. of effluent; why cannot he discharge that?

He would, moreover, be economising in water too, a matter which should appeal to a river authority which is now the custodian of water resources. It could hardly refuse at least to give consideration to the case of the manufacturer.

It is, of course, not quite true, even on an arithmetical basis, that the effect of an effluent on a river is proportional to its volume multiplied by the concentration of its impurities. For instance, 1 m.g.d. of effluent of B.O.D. 40 mg/l discharged to 10 m.g.d. of a river of B.O.D. zero would give a mixture of B.O.D. 3·64 mg/l, whereas 2 m.g.d. of effluent of B.O.D. 20 mg/l would give a mixture of B.O.D. 3·33 mg/l. The latter would, of course, be better, but not much. Cases have been known where (taking the above figures as examples) a firm has added an extra 1 m.g.d. of pure water to its effluent to convert it from 1 m.g.d. at B.O.D. 40 mg/l to 2 m.g.d. at B.O.D. 20 mg/l. Although the effect of good water in diluting effluents is undoubtedly one of the advantages of increasing the minimum flows of rivers, the practice of using 1 m.g.d. solely for the purpose of reducing the B.O.D. of 10 m.g.d. from 3·64 to 3·33 mg/l would seem to be a very expensive process of purification and an unprofitable use of good water unless it happened to be both plentiful and cheap.

Qualitatively, too, it is only as a first approximation that the effect of a discharge is equal to its volume multiplied by strength (B.O.D.). It is probably not true that 100,000 g.p.d. of settled sewage of B.O.D. 200 mg/l has the same effect as 1 m.g.d. of purified sewage of B.O.D. 20 mg/l. From the pollution angle, the latter may be preferable; the former might give rise to sewage fungus, for instance, whereas the latter would probably not. The precise nature of the B.O.D. as well as the amount may be important. And, of course, the precise nature of the B.O.D. of a food effluent may not be the same as that of a purified sewage.

It will be helpful to river authorities if they divide such effluents (and, indeed, all industrial effluents) into those which already exist, those which are new, and those which have become altered.

If one which exists gives rise to no nuisance nor interferes with any existing use of a river, then there would seem no reason to press for improvement whatever its composition until circumstances change. Additional discharges to the same river or new uses of the river would be changed circumstances for this purpose. If it gives rise to a nuisance only occasionally then a moderate improvement may be necessary, and so on. The point is that the river authority will already have a good idea of the effect of an improvement, or of the improvement necessary for a desired effect.

If the discharge is a new one they have no such knowledge, and accordingly, any assessment they may make of its effect will be less reliable. Moreover, they will know that if they allow any pollution in the discharge at all, the quality of the river must deteriorate, however little. They will also be very conscious of their function "to restore and maintain the wholesomeness of rivers". It is very possible that, in these circumstances, they will be tempted to lay down conditions incorporating a very high factor of safety, and they could be accused of being too restrictive.

It is only right that any manufacturer, and indeed any sewerage authority, who proposes a new discharge into a river should be told the worst possible at the outset. If the river authority believe that there is even a small chance of a very high standard being necessary they should so inform the potential discharger, who would then be very foolish if his plans did not take this possibility into account. But this is not to say that they should demand such a high standard from the start. There is much to be said for demanding a lower one, one that the authority believe that, all in all, will be all right, but about which there is not nearly absolute certainty.

It is sometimes said that rivers should be kept unpolluted no matter what the cost. Others maintain that we should not keep rivers cleaner than we can afford to do. These differing points of view will no doubt continue to be argued about for years, but no one has ever maintained, as far as can be ascertained, that if satisfactory results can be obtained for x million pounds then it would be a good thing to spend 2x million pounds. No one wants sheer waste of money. But this is not very different from saying that, because it is only probable and not absolutely certain that x million pounds will produce a sufficiently good result, somebody must spend 2x million pounds. In this case it is only probable and not absolutely certain that there would be a sheer waste of money. But it is surely worth while stopping to make certain. This is one of the advantages of not asking too much at the start.

Another is that, because it is not customary to start off with the maximum discharge, it permits useful information to be obtained at very little risk. If it is felt that a particular standard might possibly be required at the ultimate discharge rate, it is probably fairly easy to arrange for the first stage of development to produce an effluent conforming to such a standard. But it might be more profitable to knowledge to allow it to conform to a relaxed standard so as to simulate as far as possible (though not, as explained above, completely) the effect of the greater volume at the higher standard. This would provide good evidence of the standard which would ultimately be required, and it could save a lot of both time and argument.

OTHER ORGANIC EFFLUENTS

This class is meant to include effluents from such industries as paper, leather, wool and cotton textiles, some synthetic textiles, etc. These are similar to effluents from food and drink manufacture in that the raw materials for the industry are animal or vegetable matter and consequently most of the impurity present in the effluents consists of organic matter. The reason they are put in a different class is because the organic matter may no longer be in its natural state and therefore may not always all be oxidisable by biological means. Some of them may have other pollutants present too, e.g., chromium compounds in leather effluents, strong alkalies in paper effluents and synthetic dyes in textile effluents.

All that has been said in the previous section applies to this class of effluents. In general, they can be biologically treated, though preliminary neutralisation may be necessary and it may be profitable to use another process first, such as precipitation of grease from some effluents from the wool industry. Their content of nutrients may also be more unbalanced, and some of them may be very concentrated. Nevertheless, biological treatment of them is widely carried out, particularly with sewage at local authority works, and often with little trouble. Accordingly, criteria of B.O.D. and suspended solids are entirely suitable for assessing the quality of these effluents. The limits to be imposed will, of course, be arrived at as already explained. They may also be combined with an ammonia limit, though this should only rarely be necessary since they are more likely than not to be deficient in nitrogen content.

For these effluents however the criteria of B.O.D. and suspended solids may not always be sufficient, depending on the use of the river. pH may be important, though the fixing of limits should present little difficulty in the normal case. In assessing them not only should relative volumes be taken into account, but the buffering capacities of both effluent and river water. In a lightly buffered stream containing ammonia as one of its pollutants, any increase in pH will increase the toxicity of the ammonia but, on the other hand, will serve to neutralise the nitric acid produced by nitrification. Sometimes a chromium or a sulphide limit may be necessary. In the case of the former a clear distinction should be made between hexavalent chromium (chromate) and trivalent chromium (chromic salts).

Effluents in this group are, on the whole, more likely to contain some organic matter which either oxidises very slowly or is entirely non-degradable by biological action. This may therefore be the proper place to discuss the importance of such materials. Up to the present time they have not often been of great significance. The industries whose effluents are in the present class have been largely located on rivers not used as sources of water supply. The resistant compounds have generally proved non-toxic to fish — at least, where rivers containing them have been fishless the primary reason has been lack of oxygen — and the time of travel to the sea has been short.

A rough and ready measure of the organic matter in an effluent is given by the permanganate test, but the figure has more often been taken as an indication of how much still remains to be oxidised rather than how much will not oxidise. Sometimes, for instance, when B.O.D. determination may be subject to interference, the permanganate value has taken its place as a standard; sometimes both have been used for the same effluent.

But the circumstances are changing, and it is becoming important to know more exactly how much organic impurity, irrespective of its response to biological action, is present in a river. Indeed, the impurity might well be more important if it were not broken down. Recently it has been established that there are minute traces of D.D.T. in our rivers. The concentrations are orders of magnitude too low to have any direct effect upon human health, and if D.D.T. were decomposed by bacteria no one would think the amounts present worth a second thought. It is because they are not so destroyed that it is necessary to keep a watch on their concentration.

In the future it seems certain that the rivers from which we get our water supplies will contain a greater proportion of both domestic and industrial effluents. It is also probable that we may have to use rivers which have not hitherto been thought suitable. It may never be possible to establish the safety of such sources, after treatment, by analysis for each and every possible harmful impurity. Safety will have to be ensured in other ways, one of which will be the determination of the total amount of organic impurity and where it comes from. It may be necessary to limit it in some industrial effluents.

It seems possible that the most convenient measure of total organic matter will be a chemical oxygen demand test (C.O.D.) using acid dichromate as the oxidising agent. It would be very useful if river authorities, sewage disposal authorities and the industrialists concerned deliberately set out to get experience with this test. It is not suggested that limits based on it should appear in river authorities' conditions of consent at present, though as soon as sufficient experience is available it could profitably replace permanganate value if that is now used. But in future — perhaps not very distant — it may be necessary to use it extensively.

Alternatively, a direct estimation of organic carbon might be equally useful. This is certainly being considered in some quarters, and deserves to be encouraged.

Some effluents in this group may also contain specific noxious compounds or compounds of metals toxic to fish and unacceptable in a water supply. In so far as they do, they may be considered to be also in the remaining classes of effluents and dealt with, as far as may be necessary, as discussed in the following sections.

EFFLUENTS CONTAINING METALS AND CYANIDES

These are largely produced in what may be broadly termed the engineering industry. Cyanides are included with metals because of their use in metal plating, and they often occur together in effluents from the same factory. With the exception of iron, which must be considered separately, their most important characteristic is their extreme toxicity to fish, about which a great deal is now known. Quite frequently, too, these effluents are relatively free from other organic matter, though from a general engineering factory quantities of oil may be present either in emulsion or in suspension. Biological processes can therefore play but a limited part in the treatment of these effluents. On the other hand, some of them can have an important inhibiting effect upon biological processes and may make sewage or sludge much more difficult to treat. Yet, more often than not, because of the location of the factories the effluents are discharged to the sewers and enter the rivers with local authority sewage. They therefore pose problems both to sewage disposal and river authorities, but it is the latter which are being dealt with in this paper.

Taking iron compounds first as being the easier to deal with, they ought not to constitute a severe problem to river authorities in the laying down of standards. If iron is discharged as a ferrous salt it will take up oxygen and become a ferric salt. This process will utilise dissolved oxygen in the river, but it may not be controllable by a B.O.D. limitation because the oxygen demand might be exerted before the "blank" of the B.O.D. test is titrated. The oxygen demand can, however, be perfectly easily calculated. If pH of the river is within the normal range, the ferric salt will hydrolise and ferric hydroxide will be precipitated. The precipitate will not deposit sludge which gives rise to objectionable odours, and the coagulating effect of the ferric hydroxide might even "purify" the river water to some extent. But it is highly coloured, and could give rise to turbidity where none existed before. On the whole it would appear to be reasonable and adequate to deal with ferrous iron on the basis of its oxygen demand and with total iron as though it were suspended matter. Depending on the effluent, the suspended matter would be determined after oxidation of the iron in neutral solution or the determined value could be increased by the equivalent of iron oxide in solution at the time the test is carried out.

Salts of such metals as copper, zinc, nickel, cadmium and lead are often grouped together under the term "toxic metals". Above certain very small concentrations they are toxic to men, to fish, and to other aquatic fauna and flora. Whether toxicity to men need be taken account of or not by river authorities depends largely upon whether the river is used as a public water supply, though one would not want the concentration in a river to be so great that a man would be almost bound to be poisoned by the amount of water accidently drunk if he happened to fall in.

When the problem of toxicity to men is the most important its solution should not be very difficult provided certain factors are borne in mind. First, since all water from rivers is fully treated before being put into supply, only metals in true solution at the intake need to be considered; all suspended and colloidal matter is removed during treatment. Secondly, there is no complication requiring the dissolved oxygen content of the water to be taken into account in assessing permissible concentrations. There is no evidence, nor likely to be, that the effect of these metals on man is in any way influenced by the dissolved oxygen in the water. Thirdly, the World Health Organisation standards for drinking water form a useful, though not necessarily absolute, guide in these circumstances. Fourthly, it is the concentration at the water intake and not that where the effluent is discharged which is important. Calculation of permissible limits in discharges must take into account the stream flow at the point of abstraction and all the metal-containing effluents discharged above that point. Fifthly, should the metal contents of the river approach the permissible limits for water supply, it would be useful to know exactly how much, if any, of the metals in solution are removed by treatment and whether any change in pH made for treatment purposes could affect the solubility of the metals.

It is likely, however, that in most cases the limitation in metal content of effluents will need to be more severe to protect fish than to protect drinking water. This is not because fish are more important than men. It is partly because fish are more sensitive to contaminated water (having to live in it), at least as far as some metals are concerned, and partly because drinking water abstraction points on a river are few and almost certain to be at places where there is a greater dilution than there will be in some stretches where fish are desired. It is fortunate, therefore, that safe tolerances for fish are often known more accurately than safe tolerances for men; it is permissible, under proper control, to determine the former experimentally.

Many of our rivers, particularly the shorter ones and the industrial ones, are not used for water supply at all. When it is intended to make use of one, the proposals are worked out in detail and submitted for scrutiny and possible objection by interested parties; there may well be a public inquiry, and the matter is decided once and for all as one of policy. On the other hand, most of our rivers already contain fish, though some do not because of pollution. When an effort is to be made to restore one of these rivers to a fishable condition there is no procedure parallel with the one described for water supply — no formal plan, no opportunity for objection, and no public inquiry. The nearest approach to it would be a policy decision by the river authority,* an appeal by a trader, or a sewage treatment authority, against standards necessitated by that policy, and a decision of the Minister on those particular standards.

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* This Memorandum is not concerned with common law.

It is not the purpose of this Memorandum to discuss such matters of policy, and it may be as well to repeat what was said earlier, that no attempt is being made to undermine or usurp the functions of the river authority who are primarily responsible for policy. But technical factors should influence policy, and since as often as not it is the presence of too great a concentration of toxic chemicals which is responsible for fishless rivers, certain factors which policy might take into account should be mentioned in this section.

First, the greater sensitivity of fish to some poisons means that considerable reassurance about the quality of a public supply is given if it is known that it is taken from a river in which fish are living. It is not a complete reassurance, but it is one well worth having. Also, if there is a fish kill above the intakes, somebody becomes aware of it quickly and steps can be taken to determine why it has occurred and to ensure that no water which will adversely affect human health is sent into supply. It is therefore a useful policy, and one which will not be widely challenged, to maintain a river intended as a source of public supply in a condition where it will readily support fish, too.

In only one important case has it ever been openly decided not to attempt to restore a badly polluted river to a fish-supporting condition, and that was with regard to the tidal River Thames. This policy was recommended by the Committee concerned and is, at least for the present, being operated by the Port of London Authority. But there must be several other cases where such a policy has been tacitly adopted. It would be easy to name streams in most of our conurbations which neither members of river authorities nor the general public expect to contain fish in the foreseeable future. This may be because of excessive cost, because of their position in any reasonable list of priorities, or for some other reason. Whatever the reason, it is suggested that in such cases it would not be justifiable to lay down limits for metals or other toxic substances in order to protect fish life. This would be like putting a fence around the cliff edges of an uninhabited island so that no one could fall accidentally into the sea. It may, however, be necessary to lay down limits to protect fish life further downstream where the tacitly accepted fishless river joins a larger one which should maintain fish. In calculating such limits, however, the total discharges above the point in question should be related to the total flow at the same point and not the point of discharge.

When it comes to laying down the actual limits of concentration, a river authority will wish to incorporate a factor of safety. This is right and proper; to maintain a river which can just, and only just, support fish life, be an acceptable source of public supply, or be suitable for any other planned use, is probably impracticable, and certainly an undesirable policy. (We do not build houses which will only just not fall down.) But to have too large a factor of safety may mean a waste of precise information and expenditure we cannot afford. (We know more than we did about properties of materials, and do not waste money building houses with walls as thick as some of the old cottages we see.) River authorities must somehow steer a middle course between not doing their job properly (by working to too narrow a safety margin) and not doing their job reasonably (by insisting on too high a factor of safety), as is the implied requirement of Section 7 of the Rivers (Prevention of Pollution) Act, 1951.

So far as health risks to men are concerned, it may be taken that the W.H.O. limits for toxic materials already incorporate adequate factors of safety, which should simplify the task of river authorities. So far as fish are concerned, much of the information available is of concentrations of metals that will kill half the fish present under highly artificial conditions in a relatively short time—a few days. Sometimes the concentration is known that will not apparently harm fish in a period of a few weeks. But rarely can it be said that a certain concentration has been proved to be tolerable indefinitely without any damage at all to a fishery. To all this must be added the fact that toxicity to fish may depend upon oxygen concentration, pH, hardness of water, temperature and other factors. All these must combine to tempt river authorities very strongly to provide a very high factor of safety and consequently to require industry and local authorities to spend a great deal of money—possibly unnecessarily great and perhaps too great to be contemplated.

There are, however, two other points which must be considered and which, separately or together, may ease the situation considerably. The first one necessitates a mention of an indication relating to the effect of mixtures of poisons on fish. It appears that in many cases toxicities are additive, so that the combined effect can be expressed as that of the sum of the concentrations of the toxic constituents, when each concentration is expressed as a proportion of that which would be fatal in a given time, usually two or three days. Thus, if the toxic concentrations (those which would kill 50% of fish in, say, two days) of a number of substances are A, B, C . . . and the actual concentrations in a water are a, b, c . . . , then if $a/A + b/B + c/C$ . . . are equal to unity, then that water would also be expected to kill 50% of fish in two days. Using such a formula for the known toxic constituents of some actual rivers gives results which permit a (tentative only) generalisation that if the sum of the fractions averages no more than 0·3 to 0·4 (that is, 30 - 40% of the concentration which would be fatal in a few days) then fish life is usually present provided the dissolved oxygen is adequate. In other words, the factor by which a concentration known to be lethal in a few days must be reduced to become substantially non-toxic may prove to be quite small. It is perhaps too much to hope for this to be true for all poisons, but it is useful to know that it applies to some of the more common ones.

The second point is almost the converse of the oft-quoted dictum: "Fish only die once". So far as individual fish are concerned this is perfectly true, and the dictum is quite properly quoted to get the point over that, where fish life is concerned, average concentrations are no reliable guide. If a river is toxic on Tuesdays, it is no satisfaction to know that it is so free from toxic material during the rest of the week that on average a toxic level is not reached. You cannot say of fish life like you can of a railway train: "does not run on Tuesdays", and you cannot control a river on average toxic discharges.

That having been said, however, there are facts like the following to consider. During the last war there was an accidental discharge of cyanide which killed all the fish in a certain stretch of river. A few months later a similar occurrence in the same place killed an equal number of fish. Within a year there were four such discharges, and on each occasion a very large number of fish in the same stretch of river were killed. In one sense, those fish had died four times!

A fish kill is, of course, regrettable. Damage is done, and there can be no question that the damage should be paid for. But it is the sort of damage which, once the factors causing the damage are removed, is repairable and often "self-repairable", fairly quickly too. A large safety factor involving a correspondingly high cost may not be justifiable.

It is believed that these considerations may also help in deciding for what river flows to "tailor" the consent conditions. Ought they to be for the smallest conceivable flows? Or should a real risk of fish kills be taken in such circumstances? There is a lot to be said for following the policies of engineers in somewhat parallel circumstances. A flood prevention scheme is not intended to prevent the worst conceivable flood; it only reduces the frequency of flooding to an accepted 1 in 5 or 1 in 50 years, depending on the damage it causes when it occurs. The possibility of a certain amount of damage is accepted; it is much cheaper to pay for it when it occurs than it is to prevent it occurring. This is right when the damage is repairable or can be compensated for financially. It would not be right to adopt the same attitude where human life is concerned, but fish are not human. What anglers and others who value fish in rivers are interested in is not the life of a particular fish, which is not restorable, but fish life, which is.

It is suggested, therefore, that consent conditions should not normally be so restrictive that not a fish will die even if the river flow is reduced to the lowest it is possible to conceive. On the other hand, it will be accepted that they should not be so lax that fish kills occur at flows reached every year. Between these two extremes, it is believed that a sound judgment could be reached by a careful assessment of the local situation, taking into account flow frequencies, other uses of the river, extent of fishing stream involved, magnitude of discharge, economics of treatment and other factors.

Following the passing of the Rivers (Prevention of Pollution) Act, 1951, the Ministry of Agriculture, Fisheries and Food worked out, and later published, a standardised test for toxicity to fish. It has been widely used for determining toxicities of new chemicals for use in agriculture. A service to industry and others is available at a fixed charge per sample, in return for which the concentration of a substance (or an effluent) which will kill 50% of fish under the standard conditions is provided. It was hoped that eventually such a figure might appear in river authority consents to discharge, in some such form as "the effluent, when diluted 'X' times, shall not kill more than 50% of fish when tested under the conditions of the standard test". So far this has not been possible. Meanwhile, at least one river authority has been gaining experience with a fish toxicity test of its own devising which is certainly not without merit. It is very desirable that if any toxicity test is used formally in connection with consents of discharge it should be the same one throughout the country. It is hoped that an ad hoc committee will shortly make some recommendations about this.

If a fish toxicity test of proved value does come into general use it will constitute a very considerable advance in the technique of river pollution control. But it may well pose problems as well. Could it be used on a routine basis, or could it be reserved for formal samples? Should it replace altogether limits for toxic metals, cyanide and other fish poisons? No doubt it will take time to answer these questions.

Experimental information on toxicity of effluents containing metals and also other substances is plentiful, but is scattered throughout many journals, is often incomplete in the sense that the conditions are not sufficiently accurately specified, and is sometimes difficult to interpret. To meet this situation the Water Pollution Research Laboratory has established an information service on toxicity and biodegradability (which can conveniently be abbreviated to INSTAB). It has prepared an index, which is free on request, of substances for which information is available on fish toxicity and other properties important in effluents. It is the result of a search of many years' issues of some 250 journals, together with some unpublished information, and is therefore a collection of data which other organisations in the U.K. can hardly hope to match. The information is continually under review, and it was decided not to publish it as such. However, a digest of what is known about specific substances can be supplied on request, and river authorities and others will no doubt find the service invaluable. For further information see "Notes on Water Pollution No. 38, June 1966", published by H.M.S.O. for the Ministry of Technology.

CHEMICAL EFFLUENTS

This is a "miscellaneous" class, which includes all those not adequately described in the three previous groupings. In a sense they are the unclassifiables and ought, therefore, in theory, to include such effluents as those from china clay winning and gravel washing, though it is not proposed to deal with these since where they are serious problems they are highly localised and important concerns only for one or two river authorities; their objectionable constituents are suspended solids only. The group ought also to include coal washing effluents, which can contain other matters besides suspended solids, but a great deal of progress has been made in dealing with these in recent years and they need no more than a mention here.

These apart, the non-classifiable effluents come largely from the chemical industry or industries using chemicals. In their simplest form they may be no more than common salt solutions, which do not cause a nuisance and are not toxic to fish but can, if the concentration in a river is great enough, reduce its value or even prevent its use for public supply and irrigation. No exact limits can be given in either case. For public supply the limits are not those above which human health would be affected; the limits are necessary because of taint, or corrosive effects, or possibly effects on industrial uses of the supply; they are, therefore, in a sense "arguable", and may be influenced by economic and other non-medical considerations. For irrigation the tolerable concentration depends a good deal on the plants to be irrigated, and also upon the amount which is likely to be used and the expected winter rainfall which will leach out the salt again.

These effects have not yet caused widespread problems in this country, but with the increase in river supplies and in the practice of irrigation on the one hand and the increase in the volumes of sewage and industrial effluents on the other they could become severe, particularly as no cheap and readily available process of chloride, sulphate or nitrate removal is available. In semi-arid countries the increasing "mineralisation" of the available water may, in the not far distant future, prove to be the greatest water pollution problem of all. We have not reached that point in the United Kingdom and, with few exceptions, discharges of inorganic salts in local authority and industrial effluents do not themselves cause concern. It might well be that the presence of inorganic salts, particularly nitrates, in drainage from fertilised land will ultimately prove of greater importance, but this is not the subject of this Memorandum.

At the other extreme, chemical effluents include relatively small quantities of complex organic compounds, usually synthetic, which have a quite disproportionate effect upon one or more of the metabolic processes on which the wholesomeness of a river depends, or which affect the use of a river for purposes involving these processes. D.D.T., Dieldrin, BHC and some other pesticides can profoundly affect the fauna of a stream in concentrations far below any conceivable limit or concentration for organic matter generally. Substances which have been found to affect nitrification in sewage treatment processes will presumably affect it in the river too, and may prevent the necessary recovery of a river between an effluent discharge point and a public supply abstraction point. Small concentrations of certain substances prevent the digestion of sewage sludge; they might well have a most adverse effect on what happens in bottom deposits if discharged to a river.

Between these two extremes are an infinite variety of "chemicals" less innocuous than inorganic salts and not as toxic as those just mentioned. Often they are amenable to some degree of biological oxidation, and even a complex mixture can frequently be dealt with at a sewage treatment works at least to the extent of preventing them causing a subsequent nuisance in a river and any very obvious effect upon fish. Gas works' effluents were a notable instance of this class, and a large amount of work has been carried out on the treatment and disposal of liquors from the carbonisation of coal. There are several examples of a sewage treatment works dealing with general chemical effluents in quite high proportions without the management knowing in any detail what the individual constituents are. So long as the receiving stream is not used as a water supply, so long as the works is adequate and well managed, and subject to co-operation from the main manufacturing works involved, this seems a satisfactory modus operandi without it being necessary for a river authority to lay down too detailed a consent. It might be less satisfactory and would certainly give rise to more anxiety if the chemical industry concerned were a rapidly developing one, continually introducing new processes and expanding and modifying old ones, and if the receiving stream were the source of a public supply without a very large dilution. It is in these circumstances that the most whole-hearted collaboration, the closest supervision, the most detailed consents, and the largest safety factors are most easily justified. All these are expensive, and could be so expensive as to make it undesirable economically (as well as for other reasons) for such circumstances to exist if they can possibly be avoided.

ESTUARIES

This leads to the question of tidal waters, because there has been a marked tendency in recent years for the chemical industry, and some others, to establish itself on estuaries which, until 1960, were largely outside river authority control and where, in any case, it was thought that relaxed effluent standards would suffice. This is sometimes, but by no means invariably, the case, dependent, perhaps, on what is meant by the term "estuary", which has no precise legal meaning as far as the Pollution Control Acts are concerned. They deal with "tidal water" instead, which has been held formally to be water the level of which rises and falls diurnally with the tide. It need not be saline, it need not ebb and flow, it need not be, and often is not, distinguishable by its appearance, environment and use from non-tidal water. There are instances of public water supplies being abstracted from tidal water.

All tidal waters in England and Wales, including estuaries down to individually defined seaward limits, are now subject to the Clean Rivers (Estuaries and Tidal Waters) Act of 1960, which brings new and altered discharges, but not existing discharges, within the control of parts of the 1951 Rivers (Prevention of Pollution) Act. Some tidal waters are also subject to Orders made under Section 6 of the 1951 Act or its predecessor, which can give the river authority greater power than does the 1960 Act. Other estuaries could no doubt be made subject to such Orders, though the incentive to do so is very much less than before 1960. These matters are ignored in this technical memorandum, and what follows assumes that the powers of control of river authorities are adequate for the circumstances.

Where tidal waters are virtually indistinguishable from inland streams, commonsense suggests that the "norm" for local authority effluents accepted in the previous memorandum should apply to these waters too, though one might expect rather more cases where a local authority could successfully argue that an existing poor quality discharge does no harm and ought not to be compelled to conform. It also seems likely that industry could not hope for less restrictive conditions for discharge to such streams than for discharge to inland rivers.

In estuaries proper, however, the situation is different. Here, the waterway is much wider than one would expect for the normal river flow, it typically gets progressively wider as the sea is approached, and the point where the estuary ends and the sea begins is often not very definite. The waters are partly fresh, partly saline and partly brackish, they are sometimes stratified with salt water beneath the fresh, they are not usable after abstraction except as cooling water, and are not capable of maintaining the same sort of fishery as is the inland stream. Often their chief fishery value is the essential part they play in the life cycle of migratory fish, though sometimes shellfish are important too. All these factors can affect pollution control policy.

Many of our estuaries have become grossly polluted, and for a variety of reasons. One of these is undoubtedly that the capacity of an estuary to tolerate pollution without ill-effects has been grossly over-estimated. But this does not mean that it does not exist; it is often much greater than it would have been in the same fresh water flow with non-estuarine characteristics. Both industry and local authorities may therefore legitimately expect less restrictive conditions of discharge to estuaries than to inland rivers under otherwise comparable circumstances. The question is: how much less restrictive? The answer "not so much as you might expect" may not be very helpful, but it is right enough as far as it goes.

The exact answer can only be given estuary by estuary after a careful study of each one, but the following general points may be made.

The first is that the nearer the discharge is to the sea the less harmful it is. Although so obvious the point is still worth mentioning because there are no less than three reasons for it, each adding its weight to the others. One is that nearer the sea there is a greater degree of dilution for a discharge. The second is that the effluent reaches the open sea more quickly because it has not so far to go. The third is that, because of large volumes of sea water to landward of the discharge point at high tide, the progress of the effluent towards the sea during the ebb is much quicker than simple calculation might suggest. Altogether, the position of the discharge point is a most important factor in deciding standards.

In calculating dilution factors, misleading results would be obtained if the fresh water flow only were taken into account. Results equally misleading in the other direction would be obtained if the total volume of water passing the discharge point was taken into account, because some of this may well have passed the discharge point on previous tides and already received its quota of effluent. An approximate estimate of the average diluting water can be obtained from the total non-saline flow above the point of discharge (i.e., river and effluent flows if the effluent is non-saline), and the average chloride content near the discharge point. From the latter can be calculated the average proportion of sea water to fresh, and, since the amount of new fresh water arriving each day is known, the amount of new sea water can also be calculated, and all of it is diluting water.

It is useful to know the volume of water in the estuary, section by section and at low and high spring and neap tides. This allows some calculation of the probable detention period of an effluent from any discharge point. It also enables an assessment to be made of the advantage to be gained by storage followed by discharge around high tide and on the ebb. This will have the same effect as moving the discharge point nearer the sea, and in some cases an effluent may clear an estuary within a few hours.

If an estuary is stratified, sea water is at the bottom and therefore not immediately available for diluting an effluent which is usually less saline than sea water. This is compensated for, however, by the fact that the sea water must push itself upstream under the fresh water and at the expense of the fresh water, which must travel towards the sea correspondingly more quickly taking the effluent with it.

In a large estuary from which a discharge takes several days, or even weeks, to reach the sea proper, it is not the instantaneous discharge of effluent which determines the conditions in any particular area, but that discharge plus the discharges at corresponding times over many previous days, making allowance for both self-purification and dispersion. River authorities need not, therefore, worry too much about maximum limits; it is more nearly the average they are interested in. This could be an important factor in fixing limits.

It may also be pointed out that the limits which could be affected by this factor are not only limits of quality, but also limits of quantity treated. If the norm for sewage is three times dry weather flow treated to a 30/20 standard, then a relaxed standard may be either three times dry weather flow less fully treated, or less than three times dry weather flow to a 30/20 standard, the balance being treated by sedimentation alone; or, of course, it could be a compromise between the two. If a situation is such that alternative procedures give virtually the same result, then it is well worth while examining which is the cheaper and devising conditions to permit that one to be used.

If the main fishery importance of an estuary is to provide safe passage for migratory fish, the high dissolved oxygen contents needed in a breeding river may not be necessary in an estuary. By contrast, however, if part of the estuary is used for shellfish cultivation, there would be a demand for a much better bacteriological condition than is required in most inland rivers. This is too wide a subject to be opened up in the present paper, as is the question of bathing beaches within an estuary. They are better dealt with in a memorandum on pollution of the sea.

The most widely studied estuary in this country, and perhaps in the world, is the tidal Thames, which has been the subject of a policy report and a later, and much longer, technical report. This study was greatly helped by the surveys made by the London County Council regularly over many decades and the results fortunately preserved. For most other estuaries such long term records are largely lacking. Nevertheless, the work on the Thames has helped to indicate how short, intensive surveys on other estuaries can yield the maximum amount of information, and these are to be commended.

It was found possible to construct a mathematical model of the tidal Thames by the aid of which the effect of polluting discharges at any point on the dissolved oxygen regime could be calculated. This is expected to prove an adequate tool for future river management, because the chief threat to the Thames is lack of oxygen and not toxicity or other specific property. It is interesting to note that in general it is not necessary to control suspended solids as such, though their effect on oxygen demand must, of course, be taken into account. On the other hand, it is necessary on the Thames to take the ammonia content into consideration in calculating oxygen demand, because nitrification occurs in many parts of the estuary. This will certainly not be true for all estuaries, and is one of the matters to be determined.

If any change is desired in an estuary it is certain that no informed opinion can be given about it without knowing the facts. If it is desired to clean it up, then it must be known in what direction it needs it and how much is necessary. If it is desired to make new discharges into it, then enough must be known of the existing regime and the proposed discharges to estimate their effect. In neither case will it yet be possible to give an accurate answer, though ultimately it may become possible to make reasonably accurate forecasts relating to any given set of conditions. But even now a large amount of wasteful expenditure might be avoided by the skilled interpretation of data which can be accumulated in a relatively short time. The Water Pollution Research Laboratory, in "Notes on Water Pollution No. 12", gives good advice on surveys of estuaries. Note No. 11 discussed the effects of pollution in more detail than is done in this paper.

In estuaries, conditions influencing response to pollution are even more varied than in non-tidal rivers. The influence of height of tide may be very marked, variations in wind may greatly affect re-aeration rate, and dredging practices may be important, as well as the more usual factors like fresh water flow, temperature, bottom deposits, photosynthesis, and so on. If all these happen to combine to become unfavourable at the same time, very high standards of purity might be necessary to meet the resulting conditions. The difference in costs in maintaining an estuary satisfactorily at all times and for 99% of the time may therefore be even larger than for non-tidal rivers. On this it may be noted that an opinion was once expressed that, if an estuary were passable to migratory fish nine years out of ten, then a satisfactory fishery could be maintained. This is not put forward as a target to be aimed at, but as supporting the contention that a target somewhat less than 100% can be satisfactory, and that the aim could properly be limited to the point where costs begin to rise very steeply in relation to benefits secured.

WAYS OF REACHING STANDARDS

The previous paper dealt not only with standards, but with processes which might achieve them. This was possible because of its limited field; it was only necessary to discuss how one could treat a Royal Commission effluent so that it reached a standard more restrictive and based on the same or related criteria. To do the same thing in relation to the standards discussed in this paper would necessitate considering in some detail the whole field of sewage and industrial effluent treatment; it is not therefore attempted.

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